AN

INAUGURAL ESSAY,

ON THE

EYE,

AND

ON VISION.

SUBMITTED

TO THE EXAMINATION OF

THE

REV. JOHN ANDREWS, D. D. PROVOST, (Pro Tem.)

THE

TRUSTEES AND MEDICAL PROFESSORS

OF THE

UNIVERSITY OF PENNSYLVANIA,

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FOR THE DEGREE OF DOCTOR OF MEDICINE.

By ELISHA DE BUTTS,

OF MARYLAND.

HONORARY MEMBER OF THE PHILADELPHIA MEDICAL SOCIETY.

"Sit lux....et lux fuit."

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1805.

TO

DOCTOR SAMUEL DE BUTTS,

MOUNT-WELBY, MARYLAND.

DEAR SIR,

ALTHOUGH fully conscious of the imperfection of the following Essay, yet impelled by motives of gratitude and affection, I must beg leave to offer this small tribute of my respect, to you, from whom I have received so many proofs of friendship; and under whose auspices I received the first principles of that science to which my future life is to be devoted.

In this, my first literary attempt, you will no doubt discover many errors; for which, in addition to the difficulty of the subject, I may justly plead indisposition; and I can now only wish that it were more worthy of your attention. But inadequate as it may prove, to withstand the test of critical disquisition, I do not hesitate to dedicate it to you, as the only method by which I can, at present, acknowledge the sentiments of high respect for your character, which exist in the breast of

Dear Sir,

Your affectionate and

Very humble servant,

THE AUTHOR.

TO

DOCTOR CASPAR WISTAR,

ADJUNCT PROFESSOR

OF

ANATOMY,

IN THE

UNIVERSITY OF PENNSYLVANIA,

THIS ESSAY,

IS ALSO DEDICATED

AS A TESTIMONY OF RESPECT,

AND

ESTEEM FOR HIS NUMEROUS VIRTUES,

AND

PROFESSIONAL TALENTS,

BY HIS

Friend, and

Very humble servant,

THE AUTHOR.

INTRODUCTION.

FEW subjects, in the animal œconomy, are more interesting, than that which I am now going to consider. The utility of a correct knowledge of the structure of the eye, and phenomena of vision, is evident to every one, without demonstration ; and in a retrospective view of the science of optics, in her most infantile state, we find the genius of her votaries, in a great measure, employed in attempting to elucidate this subject. But the state of science in general, among the antients, was too imperfect, to allow them to form correct opinions, respecting phenomena so intimately connected with the nature and properties of light, the investigation of which, required a greater extent of knowledge, than they were in possession of. To more modern philosophers, therefore, and particularly, to Sir Isaac Newton, are we indebted, for the completest investigation, and most important discoveries, relative to the nature of light, and consequently, for our most correct ideas of the manner in which vision is performed. Whether we view the organ of vision, in a phisiological or optical light, we have, on either hand, an impressive and illustrative proof of the wisdom of the Creator, and an ample fund for serious and useful reflection. The vast importance of a correct state of vision, in the most trifling affairs of life ; and the pleasure which the mind receives, in contemplating the infinite variety of sublime and beautiful objects, presented to it by nature and art, through the medium of sight, calls forth our most lively

gratitude and admiration, to those Philosophers, whose labours have instructed us in that species of knowledge, by which we are enabled, literally, to give sight to the blind, and to dispense happiness to our fellow-creatures, by rescuing them from one of the greatest evils to which human nature is liable.

In attempting a treatise on this subject, when so many celebrated works are already written on it, by distinguished authors, I feel myself perhaps justly liable to the imputation of temerity: but vision was my choice; and not until I began to pay an undivided attention to it, did I find myself involved in difficulties, when it was too late to recede. This, then, I must plead as my excuse. The want of plates would necessarily render the following sheets imperfect, if they were intended to convey information to those unacquainted with the subject. But when I consider the eminent talents of the gentlemen to whose judgment I must submit them, and whose good opinion I am most anxious to acquire, every regret I should otherwise feel, for this deficiency, is entirely obviated.

SECTION I.

OF THE EYE.

AS, in a description of the eye, in order to illustrate a theory of vision, a circumstantial detail of its external parts, is not generally esteemed necessary, I will not attempt it here.

The eye is situated in a bony cavity of the head, formed by the union of seven bones of the face and cranium, called its orbit. This cavity is irregular in its figure; but is well supplied with fat and cellular substance, in order to be completely adapted to the form of its contents. In this situation, the eye is firmly retained by its muscles, nerves, blood-vessels, &c. and is defended from external injuries, by the supercilia, palpebræ and lachrymal passages. When it is detached from the above cavity, it appears to be almost spherical; but, after the fat and other appendages are carefully removed, it is found to be flattened, posteriorly; and is usually called, by anatomists, the ball, or globe of the eye. Upon an attentive examination, it appears to consist of three membranes, or coats, placed concentrically, within each other, containing transparent fluids. The first, and most external coat, is called sclerotica. At its anterior part, it forms the transparent cornea, and over every other part of its surface, it exhibits a white cartilaginous appearance, easily retaining its primitive shape, after being deprived of all its contents. To this coat, which is stronger than any of the others, are attached six muscles, used in rolling the eye in different necessary directions, the tendons of which spread over part of its surface, and contribute, not a little, to

its strength. The sclerotic coat seems to be formed by the expansion of the inner plate of the dura mater of the optic nerve; the outer plate forming the periosteum of the orbit.* The second coat, or the choroides, originates from the white cellular circle terminating the substance of the optic nerve †; and expanding, concentrically, within the sclerotica, is connected to it by vessels and cellular membrane. But at the circumference of the cornea, this cellular substance becomes much more dense, attaching the coats very firmly to each other, and is then called the ciliary band. The choroides, at this place, gives out, from every part of the circumference, certain radii, inter-intermingled with vessels, which, terminating at equal distances from the centre, leave a small hole, called the pupil, to admit the rays of light. Round the pupil, and connected to the above radii, are certain fibres, disposed in the form of a ring, which act as a sphincter muscle,‡ the former dilating, the latter contracting the pupil. The anterior surface of this part of the choroides, is termed the iris. The posterior, from its uniform resemblance, in colour, to a ripe grape, the uvea; but this circumstance alone can make any difference between them. The iris varies in colour, in different people, and before those ages of the world, when, in consequence of war or commerce, nations intermingled indiscriminately with each other, the colour of the iris was invariably peculiar to the inhabitants of different climates. In persons of fair hair and complexion, it is generally of a grey or blue colour, and in those who have black or dark hair, it generally observes various shades of hazle. The choroid coat is, externally, of a brown colour, and internally, is covered by a fine black pigment, adhering slightly to its surface. From the ciliary band, and immediately behind the uvea, the choroides produces, transversely and backwards, an extremely fine membrane, to be

* *Haller on Phys. Chap.* 16. *p.* 247.

† *Ibid, Chap.* 16. *p.* 248.

‡ *Monroe on the Eye.*

connected, apparently, to the capsule of the chrystalline lens, where, in order to be adapted to a smaller circumference, it is drawn into numerous folds, of a fan-like figure, which are called the ciliary processes. After being connected to the lens, these processes give out small points, of inconsiderable length, which float loose in the posterior chamber of the aqueous humour, and have no immediate connexion with the lens. The ciliary processes are covered by the same black pigment which lines every other part of the choroides. The third coat is the retina. This is formed by the expansion of the medullary part of the optic nerve, over the internal surface of the choroides, and proceeding along the ciliary processes, terminates at the outer edge of the chrystalline lens.* This coat is of the first consequence, in vision ; and any defect in it, is of the greatest injury to sight. Within all these coats, are contained fine pellucid fluids, termed by anatomists, humors. They possess different refractive densities, and are divided into three kinds, viz. the aqueous. chrystalline, and vitreous humors.

Before I speak particularly of these fluids, it will be necessary to describe the cornea. This, we have seen, is part of the sclerotic coat ; it is perfectly transparent, and consists of several plates, filled wtth an extremely pellucid water. It is the segment of a sphere, smaller than that which the ball of the eye, in general, describes, and, of course, projects farther forwards than any other part of its surface. The aqueous humor is situated in the anterior and posterior chambers of the eye, or all that space, first, between the iris and cornea, and secondly, between the uvea and chrystalline lens, communicating at the pupil. The chrystalline humor, or lens, is of a double convex figure, having its posterior side most convex, and is inferior to no known substance, in transparency. It is composed of numerous lamellæ, which become much denser, as they approach its centre. The whole is surrounded by a very fine capsule, with a small quantity of transparent fluid in-

* *Monroe on the Eye, chap.* 3. *sec.* 4. *p.* 96.

tervening. The chrystalline lens is situated immediately behind the pupil, and is sustained behind, by the vitreous humor, and laterally, by the ciliary processes. Its capsule is connected to that of the vitreous humor, on which, as it were, by its pressure, it forms a superficial cavity, and lies in it very securely. The vitreous humor occupies all the space between the chrystalline lens and retina, or what is usually termed the bottom of the eye. This fluid is also contained in a capsule called hydloides, with intermediate cells, formed by a fine membrane, of which there are many, but they do not observe any uniform figure. The use of these cells, is probably, to preserve so large a quantity of fluid from agitation. This humor is also perfectly transparent, allowing the rays of light to pass through to the bottom of the eye, in their primitive purity.

The optic nerves are two large nerves arising from the thalami nervorum opticorum, and passing thro' foramina in the spheroid bone, enter the ball of each eye at about twenty six degrees from the axis of vision, and sending off their medullary fibrils, on the internal surface of the choroid coat, form the retina.

The principal blood-vessel of the eye, is the opthalmic artery, a branch of the internal carotid. It enters with the optic nerve, first giving off branches to supply the sclerotic coat and integuments, and sends off branches to the external surface of the choroides, which form ramifications, and proceed forwards, to supply the circle of the uvea, and ciliary processes. A small artery also emerges from the opthalmic, or from some of its branches, and penetrating through the medullary part of the nerve, spreads over every part of the outer surface of the retina, forming a close net-work, so firmly interwoven, that anatomists have sometimes mistaken it for a membrane. This is called arteria centralis. The chrystalline lens receives a branch from this artery, which passes from the retina, through the vitreous humor, and perforates its posterior

part. The veins, in general, run more externally, than the arteries. The pellucid vessels are very numerous, and difficult of demonstration.

SECTION II.

Of Light.

AS vision depends entirely upon the mutual action of the rays of light, and refracting humors of the eye, upon each other ; and as there are certain immutable laws, by which such actions take place, it is highly necessary to consider the properties of light, in general, before we attempt to explain any theory of vision. This necessity only, could impel me to treat of a subject whose difficulties require a much abler pen ; and in arranging my subject in this order, I follow the example of the best writers on the eye, particularly Dr. Porterfield.

Light is a substance, sui generis, emitted from luminous bodies, in right lines, with an amazing velocity. The rays are so infinitely small, that Philosophers have never been able to assign to them, any correct physical breadth; and notwithstanding this, each ray is capable of being divided into seven smaller rays, possessing different colours. All transparent bodies, which allow the light to be freely transmitted through them, are called mediums, and light is only affected when passing through mediums which differ in density.* When a beam of light passes from one medium, into another, it is denomi-

* *Although the refractive power of mediums, is governed by their respective densities, yet those bodies which are composed of inflammable particles, act more strongly on the rays of light, than*

others

nated the incident beam, and its termination on the surface of the second medium, the point of incidence. Any angle which the incident beam makes, with a line drawn perpendicular to the point of incidence, is called the angle of incidence ; and the angle which it makes by reflection or refraction, with the same perpendicular, the angle of reflection or refraction. The angle of reflection is always equal to that of incidence, and the above angles are found invariably in the same plane. When a ray of light passes from a rarer into a denser medium, it is bent or refracted towards the perpendicular, or that line, before mentioned, drawn through the point of incidence ; so that the angle of refraction will be less than the angle of incidence ; and if it passes again into a rarer medium, it will be refracted from the perpendicular, and the angle will be accordingly.

To the above laws, I may add, that every object which is seen by reflection, or refraction, is always perceived in the place from whence they were last reflected, or refracted.

No philosopher has been so successful in the investigation of the properties of light, as Sir Isaac Newton ; and to his experiments, I shall pay particular attention, in the course of this Section. In all his experiments to ascertain the refrangibility and reflexibility of the rays of light, he used oblong pieces of glass, with three plane polished sides, forming a triangle, called a prism. He first proved that rays which differ in colour, differ-

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others of a milder nature, in proportion to their densities. Sir Isaac Newton supposes, that as sulphur, placed in the focus of a burning glass, is very soon inflamed ; and as all action is reciprocal, that sulphur ought to act, in a very high degree, upon light : from whence he concludes, that bodies act upon light, in proportion to the sulphureous particles which they contain.

NEWTON'S OPTICS, Page 248.

differ also in refrangibility. By viewing, through a prism, a black piece of paste-board, divided by a line into two parts, one part painted with a blue, the other with a red colour, and this paper being placed so that its sides were parallel to the prism, and both parallel to the horizon, and the cross line also, and the angle which the incident light from the window made with the paper was equal to the angle which the reflected light from the paper made with the eye, the walls of the chamber round the window having been previously made black, in order to prevent any reflected light passing to the edges of the paper, and confusing the experiment. Then turning the prism slowly on its axis, he found that the blue half was lifted higher by the refraction than the red half, and by turning the refracting angle downwards, the blue half was carried lower than the red; from which he concluded, that the two colours differ in refrangibility, and that the red is less refrangible than the blue.

He next proceeded to prove that the sun's light consists of rays differing in refrangibility, by allowing a single beam of the sun's light to pass through a prism, to a plain surface stationed to receive it, where it instantly exhibited an oblong spectrum of colours, of which he counted seven, and these colours appeared in the following order, viz. red, orange, yellow, green, blue, indigo, violet. Now the angles which these rays made with the perpendicular, were different, each making a separate angle, consequently their degrees of refrangibility were various, and the violet making the greatest angle and the red the least, the former is most and the latter least refrangible; the other rays possessing their degrees of refrangibility in intermediate proportions. These rays were immutable, no second refraction being capable of making any alteration in them, and the above he proved by a variety of experiments. But as the seven homogeneal rays in the coloured spectrum, were mingled so much with each other, that they appeared to the eye in a certain degree heterogeneal, and as this was caused by the circles

of colours answering to the diameter of the sun's disque, intermingling with each other ; he considered, that if the diameters of these circles were lessened, their centres retaining their positions as before, that the mixture would be proportionally diminished. To accomplish which, he has given the following experiment. Into his dark chamber he admitted a beamof the sun's light, and at the distance of ten or twelve feet, he placed a convex lens, which cast the image of the hole, upon a paper situated at the focal distance from the lens, and then placing between the lens and paper, near to the former, a prism, the light was refracted towards a second paper and there formed a spectrum. This spectrum was, as usual, of an oblong form, with rectilinear sides, but the mixture of homogeneous rays was considerably lessened, and the circular images of the hole were distinctly terminated, without any penumbra. Thus, by lessening the magnitude of the sun's disque, apparently, by the hole in the window shutter, the circles in the spectrum no longer answered to his whole diameter, but only to that which appeared through the hole, and the lens, by making that diameter less, rendered the circles more distinct, as above. Instead of the round hole in the window shutter, he recommends one in the shape of a long parallelogram, or of a triangle whose two sides are equal, and eight or ten times longer than its base, which may be $\frac{1}{10}$ part of an inch, for if the light be admitted in this manner the homogeneous lights will be larger and more convenient for experiments. The lens ought to be good, and the prism should have an angle of 65 or 70 degrees at least, free from veins and truly plane, and the chamber ought to be perfectly dark. In performing the above experiment, although my chamber was perfectly dark, I did not succeed so well as I wished, by reason of a great deal of reflected light from the clouds, which entered the hole in my window shutter, along with the sun's beam. I therefore made use of small tubes, blackened on the inside, which I fastened in the shutter, and allowing the beam to pass through, all the reflected light

was absorbed by the sides of the tube and the experiment succeeded much better.

When objects are viewed through a prism or any other refracting body, they always appear confused; which is owing to the various refrangibility of the rays; for if flies, the letters of a book, or any other minute objects are placed in any one of the homogeneal lights, and seen through a prism, they will appear perfectly distinct.

The sine of incidence of every ray, considered separately, is to its sine of refraction, in a given ratio. This is sufficiently evident from the experiment I have related; for there, at equal angles of incidence, each ray made a separate angle of refraction; and Sir Isaac Newton further proves this, by forming an hypothesis, assisted by a geometrical calculation, that bodies refract light by acting on its rays, in lines perpendicular to their surfaces.* All homogeneal lights are unchangeable by reflexion or refraction, and each homogeneal ray possesses a capability of being reflected, in proportion to its refrangibility. When a beam of light is refracted by a prism, and the spectrum of colours collected by a lens into a focus, a white beam will be formed equal to the incident beam. Every white beam is composed of seven rays, in different proportions, which when divided by lines into seven spaces, agree with the divisions of a musical chord; and in all attempts to constitute a white beam, the above proportions must be observed, or the beam will be coloured with the superabundant light.

The colours of all natural bodies are caused by their absorbing some of the homogeneal lights, and reflecting others; and the surface of every transparent body reflects light, in proportion as it differs from the medium with which it is in contact, in refractive density.

* *Newton's Optics, page* 68.

Having considered (although superficially) some of the most obvious phenomena of light, it will now be necessary for me to enter into an explanation of those causes by which they are produced. Light is not reflected or refracted by impinging on the solid parts of bodies. The truth of this may be made evident, by a great number of experiments:—For example—When a spectrum of colours is thrown upon a second prism, placed in such a manner as to refract all the rays, and that prism is turned gently on its axis, in order that it may be obliquely inclined to the incident rays, the most refrangible lights, (such as the blue and violet,) will be totally reflected; while the red, orange, &c. will continue to be transmitted, and by increasing the inclination of the refracting surface of the prism, they will be all reflected, one by one,—the red last of all. It is not reasonable, therefore, to suppose, that at the same obliquity of incidence, the red rays should find pores enough in the glass for its transmission, and the violet and blue meet entirely with solid particles. When light is incident, out of air, on a plate of glass, so obliquely as to be easily reflected, by placing water on some parts of the lower surface of the glass—at those parts, the light which was previously reflected, will be transmitted;—therefore, the reflection was not caused by the solid parts of the glass, but by some certain constitution of the medium with which it was in contact. That this constitution exists in all mediums, and also to a certain distance from their superficies, is demonstrable, by a property of light which I have not yet mentioned; I mean that property, by which, in passing near any body, it is deflected or turned out of its direct course, which is generally called Inflection.—For example—When a beam of the sun's light, is admitted into a dark chamber, and the edge of a knife, a hair, or any other fine substance, is placed so as to intercept part of the beam, the shadow of the intercepting body, is found to be much broader, in proportion, when the surface upon which it is received, is situated contiguous to it, than when it is removed to a greater distance from it. At the edges of these shadows, appear three fringes of colours, parallel to

each other, which vary in their order, but are always so arranged, that the most refrangible rays are nearest to the shadow. If the blade of a knife is placed in the beam, its plane intersecting it at right angles, and part of the beam is received on the blade, while the other part is suffered to pass by the edge of the knife, the light, passing in this manner, will send forth, at different angles, into the shadow, two faint luminous streams resembling the tails of comets.

The limits of this essay, will not permit me to describe the variety of experiments made on this subject, by Newton, Miraldi and others: it is sufficient to say, that they all tend to prove that bodies possess a power of acting upon the rays of light, by attracting them, at certain distances; and at greater distances repelling them; and in the experiment made with the knife, the repulsive power existed at the distance of about the 800th part of an inch;* therefore, the two streams were produced by one part of the beam passing within the sphere of the attractive power, the other, of the repellent. The circumstance of the shadow differing so much, at various distances from the object, was easily explained; because, as the above forces were only exerted at certain distances from the substances used in the experiments, all those rays which passed beyond their spheres of repulsion, would consequently proceed in their respective courses, unaffected by their action. But it was necessary to account for the separation of the rays, as they appeared in the fringes; and this was done by the hypothesis,—"that the least refrangible rays were acted upon at greater distances, than those more refrangible; and consequently, the violet and blue were nearer the shadow, than the others.

All the above circumstances tend to elucidate, in a most admirable manner, the cause of reflection and refraction; which may be thus explained—and first, we must admit, that

* *Newton's Optics, page* 302.

all bodies possess a power of acting upon the rays of light, similar to that which was shewn to be the cause of inflection: —That these attractive and repellent forces are extended over the surfaces of all refracting and reflecting mediums; the repellent power existing at the greatest distance; that these powers act in lines perpendicular to their surfaces; and that all bodies refract and reflect light, by the same power, variously exerted, in various circumstances* must also be admitted, because no more causes ought to be acknowledged in philosophy than are sufficient to explain the nature of the phenomena. Let us then suppose, that a ray of light is passing through air, to the surface of the denser medium, glass, at an angle of 40 degrees with the perpendicular at the point of incidence; it will first come into contact with the imaginary surface in which the repulsive power exists, and this force acting in the perpendicular, upon the oblique ray, will, according to the laws of motion, cause it to describe a curve round the point of incidence; and when the incident ray, in describing this curve, has passed the point of incidence, it will fly off, assisted by the repellent power, at an angle equal to that of incidence. This is what takes place in all reflections. But when the ray is incident at a less degree of obliquity, its motion will of course be more in the perpendicular, and consequently will be better enabled to resist the action of the repellent force, and will only have its velocity slightly diminished, and its direction altered in proportion to the resistance. But this velocity will be immediately increased when it arrives within the sphere of the attractive force, and it will enter the denser medium at an angle differing from that of incidence, in proportion to the power of attraction and repulsion, which the body possesses, or in other words, in proportion as the superficies of the refracting body intercedes mediums which differ most in refractive density. Keeping the above observations in consideration, we can very readily conceive the course which the ray takes in passing

* *Newton's Optics, page* 244.

from the denser medium, into the rarer, because it is then exposed to the same actions as before ; but in this case it arrives first at the attractive power, and will have its direction and velocity changed, according to the resistance, but meeting again with the repulsive force, its velocity will be increased, and it will fly off at an angle greater than that which the incident beam in the denser medium, made with the perpendicular ; that is, in passing from the denser into the rarer medium, it will be refracted from the perpendicular. In prisms, the obliquity of the refracting surfaces to the incident light, causes the separation of its constituent parts, because, at certain angles of obliquity, the seven primary rays are not equally able to resist the attractive and repellent forces. The rays of light are also separable into their homogeneous parts, by becoming incident on mediums of a certain degree of thickness, inclosed in others which differ from them in refractive density. For example,—If a convex glass is laid on a plain piece of glass, they will only come into contact at a certain point, and to a certain distance round that point, will be interposed a thin plate of air, of various degrees of thickness, according to the distance from the centre or point of contact, exhibiting circles of colours, each circle varying, in some measure, the order of its colours, as it is remote from, or contiguous to, the common centre of all the circles ; therefore, light, incident on plates of this kind, is disposed to be reflected or transmitted, according to the thickness of the medium upon which it is incident, and these dispositions always return at certain intervals :—or, light is disposed to be reflected, as the thickness of the medium, is to the numbers, 1, 3, 5, 7, 9, 11, &c. and to be transmitted at all the intermediate thicknesses, as, 0, 2, 4, 6, 8, 10, &c. for it was observable, that between the rings of colours, when the light was transmitted, the circles of colours formed by the transmitted light, were all those which were wanting to compleat the colours of the reflected light. These effects will be produced if the thin plate be denser than the surrounding medium, such as a soap bubble. If one of these is covered by a clear glass globe,

to prevent its being agitated by the external air, the same variety of colours will be seen, in succession, as the water subsides from the top to the bottom of the bubble, until, at length an intensely black spot will appear at the top, because at that place it becomes so thin, that all the light is transmitted, and immediately afterwards, the bubble breaks. Glass, also, blown very thin, exhibits the same colours much more lively; for thin transparent bodies, inclosed in a rare medium, will exhibit more vivid colours, than those which are rarer.*

The least parts of all natural bodies, are transparent; for gold, altho' a very dense substance, when made extremely thin, will allow part of the light to be transmitted. Between the parts of opake bodies, a great number of spaces exist, containing mediums differing in density from the bodies themselves; for it is by this order of things, that light is suffocated in opake bodies, by the numerous reflections made in their internal parts.

From what has been said respecting the colours of thin plates, it will be easily conceived, that a certain constitution of the parts of bodies, and their intermediate spaces, with respect to size, must exist, to render them either opake or coloured; and from the same causes, must reflect one species of colour, and transmit all the rest; for one degree of thickness will invariably reflect one kind of colour. Upon these principles are founded the colours of all natural bodies, with which the whole face of nature is enlivened. The variegated plumage of the feathered tribe:—the beautifully vivid colours presented by the western horizon at the setting of the sun:—the various tints of gold and purple, which the clouds display at that period; and the vast quantity of coloured light reflected in a clear evening, from the snowy summits of distant mountains, all originate from the reciprocal action which the great Author of nature has ordained to exist between bodies and light.

* *Newton's Optics*, p. 195.

Rays of light emanating from luminous points, are naturally divergent; but these rays may be rendered more divergent, or made to converge, by refraction, so as to meet in points similar in number and colour to those from which they proceeded; for this purpose, pieces of glass, whose surfaces are smooth and regularly convex or concave, are used, called lenses.

Lenses are of various kinds, according to the purposes for which they are designed. Of those kinds it will be sufficient here to consider two:—I mean the double convex and the concavo-convex. The former is used to refract the rays issuing from all points of an object, and collect them into a focus, at which place they will represent an image of the object; and the distance of this focus, from the lens, is always in proportion to its convexity. If a convex lens is fixed in the window shutter of a dark chamber, and a piece of paper or any other white body be placed in the focus of the lens, a compleat and lively representation of the objects situated outside of the window, will appear on the white surface, in an inverted position. In this case, all the rays emitted from the radiant points of the external objects, which are incident on the surface of the lens, are refracted, and converge so as to meet in the same number of points on the paper; but as they necessarily cross each other before they arrive at their respective foci, they become all inverted. This is properly a camera obscura; and upon the same principle, all those are made, which are found so useful in drawing perspective views, &c. If the rays are incident on the convex surface of a concavo-convex lens, they will issue from the concave surface extremely divergent, and this divergency will be in proportion as the two surfaces of the lens, differ from each other in their degrees of curvity.

SECTION III.

OF THE

MANNER IN WHICH VISION IS PERFORMED.

There is a certain innate principle, inseparable from humanity, which naturally leads us to contemplate the works of nature with a peculiar gratification. There are few periods in our lives, in which we experience a more serene satisfaction, than when, in solitude, we are occupied in viewing the stupendous height of the distant mountain, or the foaming torrents of the rushing cataract. If we turn our attention to the diversified streaks of the tulip, or the flinty crags of the rock, we are alike intuitively impelled to admire and acknowledge, the wisdom by which they were constructed. The uncultivated peasant will gaze in silent admiration, on the colours and grotesque figures of the evening clouds, with emotions which his simple language is incapable of describing : but it is only the outlines of nature which can give satisfaction to minds uninformed. The man of genius and philosopher alone can become acquainted with her diversity of tints and shades, and discover the secret touches which are imperceptibly the foundation of all the beauties in the picture.

The subject of this section, and to which the two foregoing ones were only preparatory, is highly calculated to excite more interesting reflections, than any other phenomena with which we are acquainted. Having in the first section described the form and situation of the cornea and humors of the eye in general, I will now proceed to speak of them in a more particular manner. And first, of the aqueous humor.

The aqueous humor is less dense than any other refracting humor of the eye, and is situated in the anterior and posterior chambers, between the cornea and chrystalline lens. As the cor-

nea is the segment of a concave sphere, having its concave surface towards the aqueous humor, and the anterior surface of the chrystalline lens, of a convex figure, it is plain, that the whole, supported by the surrounding parts, must be shaped like a concavo-convex lens. In consequence of this shape, all the rays, proceeding from an object, which become incident on the cornea, are refracted by the aqueous humor, and pass on thro' the pupil, to the chrystalline lens. As the lens is of a double convex figure, and a much denser medium, than the aqueous humor, the rays, in passing thro' it, suffer a very great degree of refraction. Its posterior surface is extremely convex, and the vitreous humor with which it is in contact, possesses a less degree of refractive density ; in consequence of this, each pencil of rays, in proceeding thro' to the vitreous humor, are rendered convergent, and meeting in a certain number of points on the retina, imprint on its surface a correct inverted image of the object. The inversion of the image is owing to the great degree of convexity of the posterior part of the lens, which causes the rays to decussate each other about the centre of the vitreous humor. Thus we may consider the humors as a compleat dioptric instrument, placed before the retina, and the whole a perfect camera obscura.

SECTION IV.

OF

DISTINCT AND INDISTINCT VISION.

A distinct state of vision is (presupposing that the eye is in a perfectly healthy state) a capability of adjusting itself to remote and contiguous objects, in order that they may be imprinted on the retina in a proper focal image. As some controversy has existed respecting the manner in which this ad-

justment is performed, it will perhaps not be unnecessary to give some account of the opinions which have been entertained on this subject. M. de la Hire, supposed that the eye suffered no alteration, except in the contraction and dilatation of the pupil ; and was supported in this opinion by M. le Roi, who gave as a proof, that by holding an object so close to the eye as to appear confused, and then placing a card with a small hole in it, or artificial pupil, between the eye and the object, the latter would then be plainly discernable. But this hypothesis was found to be erroneous ; for although a narrow pupil renders vision less indistinct, it is only by confining the bases of the pencils of rays proceeding from the points of an object, and by that means lessening their circles of dissipation on the retina.* Dr. Porterfield has advanced a number of very ingenious experiments, by which he proves that we are capable of changing the conformation of our eyes, and of adapting them to various distances, and that this change always follows a similar motion in the axes of vision. This change of conformation, he thinks, consists in a motion of the chrystalline lens, by means of the contraction of the ligamentum ciliare, which increases its distance from the retina, according to the distance of objects ; and as the ligamentum ciliare is convex, anteriorly, by its contraction it loses, gradually, all its convexity, and presses back a portion of the vitreous humor, which, in consequence of this, presses against the lens, and assists in moving it forwards ; this last motion, of course, pushes the aqueous humor against the cornea, which is rendered more convex ; and thus we are enabled to see near objects more distinctly. To this it was objected, that the ciliary ligaments are not muscular, and of course, have not the power of contraction. But Dr. Porterfield defends his theory, by saying, that his opponents have been led into a mistake, by supposing that all muscles were of a red colour. This, he says, is not the case ; for the muscular fibres of the stomach and intestines, have scarcely any redness in their colour. He continues, it is also certain, that the

* *Priestley on Optics, page* 641.

pupil contracts and dilates itself, according as objects are more or less luminous, and yet none of the fibres which perform those actions, are in the least degree, red. Dr. Jurin's hypothesis, related by Dr. Priestley, differs widely from the above. He also supposes a contraction of the ciliary processes, which he says, takes place when the eye is to be suited to greater distances than 15 or 16 inches ; and in consequence of this contraction, the anterior surface of the capsule of the chrystalline lens, into which their fibres are inserted, is drawn a little forwards and outwards, which causes the water within the capsule to flow from under the middle, towards the elevated part of it, and the aqueous humor must, of course, flow from the elevated parts of the capsule, towards the middle. In consequence of this, the whole anterior surface within the insertion of the ligamentum ciliare, will be reduced to a less convexity. When this contraction ceases, the capsule will return to its former situation by its own elasticity, and, being a very tender membrane, containing water between its inner surface and the lens, can readily obey the effort of the ligamentum ciliare, although so weak a muscle. Dr. Priestley refutes this doctrine by a very just observation, that this alteration of the situation of the water surrounding the lens, could make no change in the direction of the rays, unless it was possessed of a greater refractive density, than the aqueous humor,* which is certainly not probable.

The experiments instituted by Mr. Everard Home, prove, indisputably, that the eye possesses a power of changing its conformation, independent of the chrystalline lens. By means of an instrument invented by Dr. Young, which, by its determining with accuracy the changes which occur in vision, is called an Optometer, he ascertained that persons who have been deprived of their chrystalline lenses can accommodate their eyes to various distances ; and with the assistance of a convex lens, he found that they possessed a state of vision not differing materially from that to which they were accustomed when their eyes

* *Priestley on Optics, page* 650.

were perfect. The optometer is made by drawing, on a piece of paper or pasteboard, a black line, about three feet long, and placing the paper in a horizontal position, the person who is performing the experiment must look along the black line thro' two slits made in a card, so close to each other as to be within the limits of the pupil and perpendicular to the paper. Behind the card, may be placed, occasionally, a small convex lens, and holding it close to the eye, by viewing the line at a point situated a few inches from the farthest extremity, he will perceive the line divided into two, and appearing to cross each other at the place of observation. After marking this point of decussation, he must change the conformation of his eye, by looking at the line, a few inches from its nearest extremity; and if his eye is capable of altering its conformation, in proportion to the distance, he will perceive the crossing of the lines, as before.

Therefore the power which the eye possesses, to adjust itself to the distances of objects, may be exactly determined by this instrument. For the faculty with which it is endowed, in this respect, is always in proportion to the distance of the two points of decussation from other.

Mr. Home directed a person who had been deprived of the chrystalline lens, to make the experiment with the optometer in the above manner, and two places of decussation were distinctly observed by him. This man saw best in a strong light, and his eyes were much fatigued by viewing objects by candle light, the reason of which is too obvious to require any comment in this place.*

The observations of the ingenious Dr. A. Monroe seem to render all the theories depending upon a motion of the chrystalline lens, in consequence of the contraction of the ciliary processes, highly improbable. In his examinations of the retina,

* *Croonian Lect. Phil. Trans. R. S.* 1802, *part* I.

in order to determine its precise termination, he discovered, that instead of ending abruptly at the root of the ciliary processes, as had been supposed, it proceeded forwards on the internal surface of the ciliary processes, and terminated at the outer edge of the chrystalline lens,* and consequently, that the ciliary processes do not form a compleat septum between the aqueous and vitreous humors, and that the chrystalline lens has no support but what it receives from the union of its capsule with that of the vitreous humor.

It was necessary, therefore, to account for the motions by which we regulate our eyes to the distances of objects, in some other manner. This, he endeavours to prove, is accomplished in a great measure by the action of the oblique muscles and orbicularis palpebrarum. That when the oblique muscles contract, they make a strong pressure upon the ball of the eye, and elongate its axis so as considerably to increase the distance between the chrystalline lens and retina. He has given some experiments to prove, that when we attempt to discern very contiguous objects, the orbicularis muscle contracts, and by pressing upon the upper and lower parts of the cornea, renders it more convex, and consequently, the object more distinct. He placed a book so close to his eyes that the letters became indistinct; and keeping his eyelids at the distance of nearly half an inch apart, with his fingers, he was unable by any exertion of his eyes, to perceive the letters distinctly; he tried the same experiment by acting only with the attollens palpebram superiorem, but with the same effect. He then, at the same distance from the book, made an exertion to read, by acting with the orbicularis palpebrarum, so as to bring the edges of the eyelids within a quarter of an inch of each other, and discovered that he could see the letters and words very plainly. In another experiment, at the same distance from the book, when the letters became indistinct, he brought

* *Monroe on the Eye, chap.* 3, *p.* 96.

the edges of his eyelids within a quarter of an inch of each other, and then stretching them with his fingers so as to make pressure upon the upper and lower edges of the cornea, the letters appeared perfectly distinct.*

I am disposed, however, to think that the action of the oblique muscles, in assisting vision, by passing upon the ball

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* Dr. Hosack's observations on vision, do not differ, essentially, from the opinions delivered by Dr. Monroe. He also advocates the action of the external muscles in producing a change in vision; but some of his inferences are perhaps not perfectly correct. In page 18, of his paper, he asserts, that in consequence of the elongation of the eye, produced by the external muscles, "the media, viz. The aqueous, chrystalline and vitreous humors, through which the rays pass, are also lengthened; of consequence, their powers of refraction are proportionally increased, all which correspond to the general principle." But this opinion does not correspond with the general principles of optics:—For, as no change can take place in the density of the humors, by the elongation of their axes, no alteration can be produced in their refractive powers. If the Doctor alluded to any change in the conformation of their surfaces, this is equally inadmissible, (with the exception of the anterior surface of the aqueous humour.) It is very evident that no alteration occurs in the convexity of the lens, in consequence of the external pressure; and unless this was the case, the surfaces of the media with which it is in contact, would remain unaffected, and consequently the light would be refracted as before. For every change which takes place in the direction of the rays, is invariably effected at the surfaces of the refracting bodies. He also attempts to prove that in persons who squint, the inability of the distorted eye, to perceive objects distinctly at the same distance at which they are visible to the other, depends upon the irregular contraction of the abductor and adductor muscles. But this hypothesis is rather inconclusive, and by no means agrees with the experiments I have adduced in this essay. If those persons who honour this dissertation with a perusal, think that any other arguments are necessary to refute this opinion of Dr. Hosack, I must beg leave to refer them to Dr. Smith's optics, and Mr. Buffon's remarks upon this subject, related by Priestley.

of the eye, is rather improbable ; but even were it admitted, their action, in this way, must be very limited, from the following considerations :

When the pencils of rays, refracted by the humors, arrive at a focus behind the retina, or converge too much, so as to decussate before they become incident on its surface ;—(either of which takes place in all cases of indistinct vision not depending upon amaurosis or opacity) in all attempts to remedy this defect, the axis of the chrystalline lens must move in the direction of a line drawn through the axis of vision, and must always observe a position parallel to the pupil and cornea : for if by any force, it is moved sideways, out of the axis, or line drawn thro' the centre of the pupil, or rendered obliquely situated with respect to the pupil and cornea, the rays, in either case, would, by the unequal refraction, fall in a very confused manner on the retina. In order therefore, to refract the rays regularly, the chrystalline lens, pupil and cornea must be parallel to each other, and each of their motions to regulate the focal image, must be uniform.

If these motions are produced by pressure upon the eye ball, that pressure must be of an equal degree of force, on all sides ; and to effect this, the situation of the oblique muscles is very well adapted ; but they can only make an equal degree of pressure, when they are in equal states of contraction, and this is seldom or never the case. If the eye is placed obliquely and consequently but one of the oblique muscles in a state of contraction, and that by this single contraction it pressed upon the eyeball, the vitreous humor would be pressed obliquely against the lens and ciliary processes, and very much discompose their situation, which certainly does not occur. The same argument may be advanced against any pressure made by the recti muscles ; unless they both act, uniformly, together ; and when they act in this manner, the pupil is exactly in the centre

of the eyelids. The orbicularis muscle, Dr. Munroe says, assists vision by pressing upon the upper and lower edges of the cornea, and thus increases its convexity; but if we contemplate the cornea in this situation, we will find its figure very badly calculated to render vision distinct. Its form, in this case, will be elliptical, resembling the form of an egg divided longitudinally; thus its horizontal convexity is lessened and its perpendicular convexity increased. The consequence of this kind of figure certainly would be, that all perpendicular objects unless very close to the eye, would appear much smaller than natural, and all those placed horizontally with respect to the eye, would appear confused :—a round object would seem of an oval form, and the rays proceeding from all bodies would be so unequally refracted, that no compleat image could be formed on the retina. To prove the correctness of some of the above observations I made the following experiment. In a tube, half an inch in diameter, and twenty inches long, I placed transversely, several pins, at various distances from each other, then fixing my head in one position, and placing my eye very obliquely, I looked through the tube at the most distant pin, and gradually changing the conformation of my eye, by viewing each of the pins in succession, until I came to the last, which was distant nearly four inches from my eye, I found that I could perceive it very distinctly without much exertion, and by fixing my eye in a horizontal direction very much sideways, and looking at the pins through the tube, I always discovered the same result.

Sitting opposite to a window, I fixed the tube before me, firmly, in a horizontal position, and looking through it, so as that the pupil was directly in the centre of the aperture formed by the eyelids, I then with my fingers, removed the upper and under eyelids, as far from the ball of my eye as possible, and half an inch from each other, and making an exertion to view the pins in succession as before, I found that I could in this manner discern the nearest pin as distinctly as when the orbicularis muscle was at liberty to act.

I next fixed a book so close to my eyes, that the letters became indistinct; then moving my eyelids to the edge of the cornea, I stretched them with my fingers so as to make pressure upon its upper and lower edges in the manner described by Dr. Monroe, and the letters immediately became more distinct but appeared to me much longer, in the direction of the lines, than natural. The pressure which it was necessary to make on the cornea in order to produce this effect, was rather painful, and we do not find in any ordinary exertions of our eyes, the least degree of painful sensation.

From the above experiments, therefore, I am inclined to doubt the action of the external muscles in increasing our sphere of vision; and am disposed to believe that those powers by which the eye is regulated to distances, all exist within the eye itself. That motions occur somewhere in the eye is evident. The causes of those motions I am incapable of demonstrating, but will beg leave to offer a suggestion of a means by which it is very probable material changes may be effected in the eye. As the retina intervenes between the ciliary processes and chrystalline lens, the latter cannot possibly be affected by the contraction of the former, without injuring the retina; consequently it cannot be by a motion of the lens, that the eye is adjusted to the distance of objects. Any changes, then, which take place, must be in the convexity of the cornea, and to effect this, there is nothing that I know, so well situated as the ciliary processes. The probability of their possessing a power of muscular contraction has been generally admitted, and their conformation has led me to think that their fibres are arranged round the lens in repeated concentric circles, from the ciliary band to their connection with the retina near the chrystalline lens. The numerous folds into which this membrane is drawn, seem to be intended to allow the fibres to contract with more ease, for these are probably only present, when the fibres are in a quiescent state, and disappear when they are all in a state of contraction. When each of these fibres contract,

its diameter is lessened in proportion to the contraction, and the circle of the ciliary band to which they are connected must also be lessened, and consequently the cornea rendered more convex. In this order of things, the change of convexity of the cornea is regularly conducted, as it ought to be, to refract the rays incident upon it, uniformly. For the cornea is perfectly analogous to the object glass of a telescope, and those glasses must always possess a regular degree of convexity, in order to transmit the rays to the other glasses of the telescope, uniformly refracted. Those who are of opinion that it would be impossible for so tough a membrane as the sclerotica, to be affected by the ciliary processes, must recollect, that before it arrives at the circumference of the cornea, it becomes much more thin and flexible, than at any other part. That this mode of suiting the eye to different distances, is the same in all animals, is very probable; for although in the larger and stronger species of quadrupeds, we may find the sclerotica extremely hard, yet it is very reasonable to conclude, that nature has endowed their ciliary processes with a muscular irritability suitable to the rest of their system.

The precise limits of distinct vision has been made a subject of very great enquiry: Dr. Jurin, particularly, was very successful in his explanations. He places the smallest distance of perfect vision, at 4, 5, or 6 inches, in the generality of eyes; that is, the distance at which a pencil of rays will converge to a physical point on the retina; and the greatest distance, he determined at 14 feet 5 inches. This last opinion was the result of a calculation depending upon the size of the eye, the refractive property of its humors, and the apparent interval of two stars, whose distance is known. Dr. Porterfield ascertains the greatest distance of correct vision to be only 27 inches, according to his own eye. These very different opinions, led Dr. Priestley to make the following remark; "Several philosophers speak of the *farthest* as well as the *nearest* limits of distinct vision—but this language is evidently improper; since, if an ob-

ject be large enough to subtend a sufficient angle at the eye, it matters not at what distance it be placed, it being seen with equal distinctness. If persons be not short sighted, they can see by parallel rays, and some even with converging ones. What they mean by the *farthest limits of distinct vision*, seems to be the greatest distance at which a book, of a middle sized print, may be read. This is plainly Dr. Jurin's meaning, for he says that this limit varies with the size of the print."* But limits doubtless may be fixed to the distance of objects, under certain circumstances, and from all the experiments related by Doctor Priestley, and others, on this subject, I would draw the following conclusions. That all eyes have the power of adjusting themselves so as to refract pencils of rays incident on their corneas, to a greater or less degree. That some eyes will consequently be able to view an object distinctly, when placed at all the intermediate distances between 4 and 37 inches (which is the distance that a middle sized print is distinctly visible to my own eyes) and other eyes will not perceive the same object at more than 20 inches, or at a less distance than 7 inches. That beyond those limits, objects are only distinct, in proportion to their subtending angles, and the force with which their rays act on the sensible retina, which, for the most part, depends on the quantity of light reflected from them, and their colour. That in our judgment of the apparent place of objects, we are always liable to error, and that experience alone can rectify these errors.

Dr. Porterfield alledges that the surest way of judging of the distances of objects, is, by observing the angles made with the optic axes; for he compares our eyes to two stations from which distances are taken, and this he says is the reason that persons blind of one eye, so often fail in snuffing a candle, pouring liquor into a glass, &c. But in viewing very remote objects, this rule will by no means answer; for then the optic angles are comparatively too small for the mind to form any

* *Priestley on Optics, vol. 2, page 650.*

judgment by them ; and when this is the case, the only method, I believe, by which we can form any judgment of their distance, is in proportion to the confusion of their outlines, and faintness of their colour. This rule has long since been obvious to landscape painters.

As every part of the human system is subject to various states of imperfection and decay, in passing through the different stages of earthly existence, this decay is evident no where more than in the operations of sight. The eyes of children are much smaller than those of adults. Their humors are of but little refractive density, and their corneas are much more flexible than at a later period. They are consequently enabled to see at small distances. On the contrary, elderly people see objects at a moderate distance, better than those more contiguous, and this for the following reasons ;—The irritability of their muscular fibres is much lessened ; every part of their system becomes more condensed; and the fluids bear a lessproportion to the solids than formerly. The sclerotica, of course, acquires a greater rigidity. The aqueous humor, and fluids contained in the pellucid plates of the cornea are in less quantity, and the cornea, deprived of its usual support, becomes flatter and less fit to refract the rays. The chrystalline lens, in some measure loses its convexity ; a slight degree of opacity also takes place in the humors, and most probably the retina itself, loses, in a certain degree, its former sensibility. Although all these things invariably occur in old age, yet they appear sooner or later, according to the situation with respect to health and temperament of different individuals.

Some persons have their corneas naturally with too little convexity, and are obliged to remedy that deficiency by convex glasses, which are also used when the chrystalline lens happens to be too flat. On the other hand, the lens and cornea sometimes possess a degeee of convexity disproportionate to their distance from the retina ; and this defect is remedied by

concave glasses. Eyes of this latter kind are preferable to the former; for as old age advances, they become less plump, and at a time when persons of the former class are obliged to have recourse to glasses more convex, the latter are enabled to lay aside their concave ones entirely. The influence of custom, as in other things, is very evident in vision. If a person is accustomed, for any considerable length of time, to look at near objects, his eyes will become less sensible to the impression of remote objects, or rather, he will lose the faculty of adjusting his eyes so as to have a proper impression of them on the retina. For the same reason, persons who are accustomed to view remote objects, see better at great distances than other people, as is generally the case with seamen, travellers, &c. and engravers, watchmakers, &c. perceive contiguous objects better than those at great distances.

SECTION V.

OF THE SEAT OF VISION.

I have hitherto spoken of the retina, as being that part of the eye which receives the impression of the object in order to transmit it to the sensorium: and this opinion prevailed universally for a great length of time, until a very peculiar discovery of a French writer, led him to embrace a new hypothesis. M. Marriote perceived that there was one particular spot in the retina, which was totally insensible to the impression of the rays of light. And upon further examination found, that this insensibility existed only at the place where the optic nerve enters the eye-ball. He placed upon a dark wall, a small round piece of paper, about the heighth of his eye, and another

piece of the same size, about two feet on the right hand, rather lower; then shutting his left eye, he receded gradually, keeping the other eye fixed on the first paper, and when about the distance of 10 or 12 feet from the papers, he instantly lost sight of the second paper; nor was this in consequence of the obliquity of its position with respect to his eye, for he could distinguish objects plainly, situated more obliquely. This experiment was improved by M. Pecquet and M. Le Cat; but the most approved manner of performing it at present is as follows: Place three small pieces of paper, as nearly in a horizontal line as possible, about two feet apart. Then covering one eye, recede gradually from the papers in an oblique direction, keeping the other eye fixed on the outside paper next the covered eye; and when arrived at a distance about five times as great as the distance of the papers from each other, the middle one will entirely disappear, because in that situation, the rays fall exactly on the entrance of the optic nerve, and the other two papers will remain visible. This discovery led M. Marriote to suspect, that the defect was owing to the absence of the choroides at the spot where the optic nerve enters, and consequently that vision depended more (if not entirely) on the choroides, than the retina :—Another observation confirmed him in this opinion, which was, that the retina is a transparent substance, and of course transmitted the rays; from which he concluded, that it was impossible for any substance to be the proper seat of vision, which did not stop the rays in their progress; and he thought that the choroides was best adapted to receive a strong impression of the light. In this opinion he was supported by M. le Cat, and afterwards by Mr. Michell, the latter of whom argued, that it is necessary, in order that vision be distinct, that the pencils of rays flowing from the several points of an object, should meet in a focus corresponding in the same number of points, which could only take place on some uniform surface, and that the retina being uniformly nervous, and almost transparent, does not present a proper surface; and that its thickness would prevent any correct image being formed,

because if the rays came to a focus on its surface, they would again diverge, before they passed through, and excite much confusion. A variety of other objections to the retina are related by Dr. Priestley, who seems to coincide in the opinion of Mr. Michell. But I really think that the latter, in attempting to advocate the choroides, has indirectly supplied us with many arguments in favour of the retina. Particularly the following: —In the first place, he contends, that if the image is made by direct rays on the nearest surface of the retina, a great degree of confusion must arise from the light reflected from the choroides, in animals in which it is white or coloured; and it would be impossible for vision to take place at all, if the retina receives the impression from the choroides, in animals in which it is quite black; and yet he says all those animals see more distinctly than others, in whom it is of a lighter colour; and vision is most probably governed by the same laws in all animals. A second argument is, that no membrane in the system, is better suited to receive a compleat impression of external objects, than the choroides; and on the other hand, the retina receives a very faint impression or none at all. For he supposes that light is not in the least acted upon by the retina, as its density cannot be greater than that of the vitreous humor. He then goes on to advance, as very favourable to his theory, the great diversity of colour of the choroides, in different animals. For example,—Those terrestrial animals in which it is necessary to see by night, possess it of a white colour or nearly so:—Birds of prey, such as eagles, hawks, &c. requiring a very acute state of vision, have it of a very black colour; and in a great variety of quadrupeds, it is of various shades of green or blue;—Lastly, in man, who requires an accuracy in vision, at a medium between the rest of animated nature, the choroides is not so black as that of the eagle, nor so white as that of the cat. And Mr. Michell also asserts that the choroides is abundantly supplied with nerves, sufficient to transmit any impression made on it, to the sensorium. But

Mr. Michell's opinion of the thickness and transparency of the retina was certainly erroneous. According to Dr. Monroe, the optic nerves, after entering the eyeballs to form the retina, change from a white to a cineritious colour.* The distance of the retina from the choroides is extremely small, and if we consider the great number of vessels every where interspersed over its outer surface, supported by a membrane analogous to the pia mater, we will find that a very small part of that distance is occupied by the retina; from which I must conclude that a pencil of rays meeting in the smallest physical point on the retina, cannot affect it materially, when incident on its surface, although it may, as Mr. Michell supposes, diverge from that point before it meets with the choroides.

With respect to the slight transparency of the retina not favouring the impression of the image, I must only observe, that it is only necessary for the finest ray of light possible, to be incident on the surface of so delicate and sensible a membrane as the retina, to excite the motion of the nervous influence. That its thickness is so small, it is of no consequence whether or not the rays incident on its surface diverge or converge, before they meet with the choroides, because they are then beyond every instrument of sensation by which the impression of such divergency or convergency could be carried to the sensorium, and there produce a confused idea of the correct image present on the retina; and, that as in all animals, in which a distinct vision is necessary, the choroides is black, so in man we find it nearly so, and this in order that any accidental rays which fall upon it, may not be reflected back on the retina, and render confused the correct image already represented on its surface. But in animals who possess a very light coloured choroides, it is probable that a different order of things takes place. All those kinds of animals are impelled by nature to seek their food by night, or in places where very little

* *Monroe on the Eye, chap.* 3, *p.* 93.

light is admitted, and all the objects of their prey are most generally of a dark colour. Every part of their choroides reflecting back to the retina, all the light incident on its surface, must there excite an uniform sensation to which I believe it is always subject when exposed to the light: for which reason they are very careful to avoid luminous objects, which always in them, produces painful sensation. As I have observed repeatedly in cats, when I exposed their eyes to a white wall illuminated by the sun, that their pupils instantly became perfectly closed. When a cat, for instance, has discovered, in the night, a bird or a mouse, these bodies reflecting very little or no light, a proportional quantity of her choroides is darkened, and of course a certain portion of the retina is devoid of the sensation of light, which I believe would allow the sensorium to judge of the presence of the object as well as if the contrary state of things was to take place. In those of the quadruped tribe, whose choroides are green, they are found naturally to subsist on herbage, and although it may destroy a perfect accuracy of vision, with respect to all colours except green, yet it certainly assists them in seeking a species of food which is so uniformly of a green colour. Indeed we may derive a very strong argument in favour of the retina, by considering the great analogy between it and the nerve of hearing, which is also spread through the vestibulum and cochlea, in a fine medullary tunic: add to this that in the disease of amaurosis, and in diseases in which, in consequence of inflammation or any other cause, the optic nerves are compressed, vision is compleatly destroyed. The above opinions in favour of the retina are nearly those of M. de la Hire, from all which I would infer:—That the choroides acts a very important part in vision. That its colour is admirably suited to the situation and habits of each tribe of the animal creation, and that the retina alone is the medium through which they can have any idea of the presence of objects.

Various opinions have been given by authors respecting the manner in which we judge of the correct position of objects

when they are inverted on the retina. Some referring it to a principle of instinct, by which the mind judges that each pencil of rays proceeded from the opposite side,—others, that we trace the light in perpendicular lines from the place of the image on the retina. But the circumstance of the medullary fibres of the nerves decussating each other at the corpus annulare, and beginning of the medulla spinalis, has led me to believe that a similar decussation takes place of the medullary fibres of the retina, at the entrance of the optic nerves into the eye balls, and if this be the case, the inverted impressions of objects on the retina would be transmitted to the sensorium, in the contrary, and consequently their correct position. If each fibre of the retina is so small as the 36-400 part of a hair as Dr. Monroe* mentions, it will be impossible ever to ascertain this point of anatomy, by any microscopical researches.

* *Monroe on Osteol. page* 328.

To the Medical Professors of this University, I must now beg leave, to address myself, by assuring them, that the information I have derived from the useful and important instruction which their lectures, at all times, afforded, will be esteemed and cherished by me as my most valuable acquisition: and that their individual politeness and attention to me, during my stay in Philadelphia, will be always held in the most grateful remembrance.